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August 6, 2001  
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*Daniel Cannon*

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# SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT I, Yasukiyo Kunitatsu, a citizen of Japan residing at Kawasaki, Japan have invented certain new and useful improvements in

PHASE COMPENSATION METHOD AND  
OPTICAL STORAGE APPARATUS

of which the following is a specification : -

TITLE OF THE INVENTION

PHASE COMPENSATION METHOD AND OPTICAL  
STORAGE APPARATUS

5 BACKGROUND OF THE INVENTION

This application claims the benefit of a Japanese Patent Application No.2001-045385 filed February 21, 2001, in the Japanese Patent Office, the disclosure of which is hereby incorporated by  
10 reference.

1. Field of the Invention

The present invention generally relates to phase compensation methods and optical storage apparatuses, and more particularly to a phase  
15 compensation method for compensating an optical phase to improve a quality of a signal reproduced from an optical recording medium, and to an optical storage apparatus which employs such a phase compensation method.

20 As one example of an optical storage apparatus, there is an optical disk unit which writes information on and reads information from a disk by converging light emitted from a light source on the disk via a condenser lens. The disks used by  
25 such an optical disk unit include read-only CD-ROMs, DVD-ROMs, writable phase change type optical disks, magneto-optical disks and the like.

2. Description of the Related Art

In the case of a magneto-optical disk unit,  
30 information is reproduced from the magneto-optical disk by detecting a rotation direction of a polarization plane which is generated by magnetizations which are recorded in a perpendicular direction to a recording surface of the magneto-  
35 optical disk. As methods of increasing the recording density of the magneto-optical disk, there is a method which increases the recording density in

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5 a circumferential direction of the magneto-optical  
disk, and a method of increasing the recording  
density in a radial direction of the magneto-optical  
disk. In order to increase the recording density in  
the radial direction of the magneto-optical disk, a  
so-called land-groove recording system has been  
proposed in addition to a land recording system  
which records the information only on lands of the  
recording surface of the magneto-optical disk. The  
10 land-groove recording system records the information  
on both the lands and grooves of the recording  
surface of the magneto-optical disk. The groove is  
formed between two adjacent lands of the recording  
surface. When the land-groove recording system is  
15 employed, it is possible to reduce the apparent  
track pitch.

When employing the land recording system,  
an optimum value of an optical phase of a  
reproducing optical system of the magneto-optical  
20 disk unit is close to 0 degree, and a phase plate  
for phase compensation is provided to adjust phases  
of optical parts and a phase of the optical system  
as a whole. On the other hand, when employing the  
land-groove recording system, a depth of the groove  
25 with respect to the land is made greater than a  
predetermined value, so that a high-quality signal  
can be reproduced by suppressing undesirable effects  
of crosstalk from the adjacent tracks. For this  
reason, an optimum amount of phase compensation  
30 differs between a case where the signal is  
reproduced from the land and a case where the signal  
is reproduced from the groove. Therefore, when  
employing the land-groove recording system, it is  
necessary to switch the amount of phase compensation  
35 between the land signal reproduction and the groove  
signal reproduction, by switching an inclination  
angle of the phase plate.

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On the other hand, even among the magneto-optical disks employing the same land-groove recording system, the optimum amount of phase compensation differs depending on the specifications such as the wavelength of the light from the light source which is used, the depth of the groove and the track pitch. For this reason, in the case of a magneto-optical disk unit which is designed for a magneto-optical disk having a predetermined specification and employing the land-groove recording system, there was a second problem in that such a magneto-optical disk unit is unsuited for reproducing signals from magneto-optical disks having different specifications.

25 Furthermore, in the magneto-optical disk  
employing either the land recording system or the  
land-groove recording system, the optimum amount of  
phase compensation may deviate even within the same  
track (one track turn), the same zone or among a  
30 plurality of tracks of the magneto-optical disk due  
to inconsistencies introduced during the production  
process of the magneto-optical disk and inconsistent  
mounting positions of parts of the magneto-optical  
disk unit. But when the amount of phase  
35 compensation is switched between two fixed values  
between the land signal reproduction and the groove  
signal reproduction, there was a third problem in

that it is impossible to cope with the deviation in the optimum amount of phase compensation that occurs within each track.

5 SUMMARY OF THE INVENTION

Accordingly, it is a general object of the present invention to provide a novel and useful phase compensation method and optical storage apparatus, in which the problems described above are  
10 eliminated.

Another and more specific object of the present invention is to provide a phase compensation method and optical storage apparatus, which carries out an appropriate phase compensation to enable  
15 signal reproduction from both an optical recording medium employing the land recording system and an optical recording medium employing the land-groove recording system or, which carries out an appropriate phase compensation to enable signal  
20 reproduction from optical recording media having different specifications or, which carries out an appropriate phase compensation within each track of an optical recording medium. According to the phase compensation method and optical storage apparatus of  
25 the present invention, it is possible to eliminate at least one of the first, second and third problems described above.

Still another object of the present invention is to provide a phase compensation method  
30 which uses a phase plate to compensate for an optical phase of a reproduced signal in a reproducing optical system which is provided with respect to the reproduced signal from an optical recording medium, comprising the step of controlling  
35 a position of the phase plate within a predetermined variable range depending on a type of the optical recording medium, so that a carrier-to-noise ratio

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of a reproduced signal from a track which is being reproduced becomes a maximum or, a DC fluctuation of the reproduced signal becomes a minimum or, a crosstalk level from tracks adjacent to the track which is being reproduced becomes a minimum.

According to the phase compensation method of the present invention, it is possible to carry out an appropriate phase compensation to enable signal reproduction from both an optical recording medium employing the land recording system and an optical recording medium employing the land-groove recording system or, carry out an appropriate phase compensation to enable signal reproduction from optical recording media having different specifications or, carry out an appropriate phase compensation within each track of an optical recording medium.

A further object of the present invention is to provide a phase compensation method which uses a phase plate to compensate for an optical phase of a reproduced signal in a reproducing optical system which is provided with respect to the reproduced signal from an optical recording medium, comprising the steps of (a) detecting a position of the phase plate where a carrier-to-noise ratio of a reproduced signal from a track which is being reproduced becomes a maximum or, a DC fluctuation of the reproduced signal becomes a minimum or, a crosstalk level from tracks adjacent to the track which is being reproduced becomes a minimum, (b) storing control data related to the position of the phase plate depending on a type of the optical recording medium, and (c) controlling the position of the phase plate within a predetermined variable range based on the control data. According to the phase compensation method of the present invention, it is possible to carry out an appropriate phase

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recording medium. Furthermore, even if the optical storage apparatus receives an external disturbance such as shock during operation and the position of the phase plate changes, it is possible to quickly  
5 return the phase plate to its original position because the inclination angle of the phase plate is controlled based on the control data and the position detection. As a result, it is possible to improve the reliability of the optical storage  
10 apparatus.

Other objects and further features of the present invention will be apparent from the following detailed description when read in conjunction with the accompanying drawings.

15 BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a system block diagram showing a structure of a first embodiment of an optical storage apparatus according to the present  
20 invention;

FIG. 2 is a cross sectional view showing a general structure of an enclosure;

FIGS. 3A and 3B respectively are diagrams showing a structure of an important part within the  
25 enclosure;

FIG. 4 is a plan view showing a part of the important part shown in FIG. 3 on an enlarged scale;

FIG. 5 is a bottom view showing a part of  
30 the important part shown in FIG. 3 on an enlarged scale;

FIG. 6 is a perspective view showing a phase compensation mechanism;

FIG. 7 is a plan view showing the phase  
35 compensation mechanism;

FIG. 8 is a diagram for explaining an embodiment of a reflection mirror;

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FIG. 9 is a diagram for explaining another embodiment of the reflection mirror;

FIG. 10 is a diagram showing a relationship of an inclination angle of a phase plate and a detector output;

FIG. 11 is a diagram showing a relationship of an optical phase and the inclination angle of the phase plate;

FIG. 12 is a diagram showing a relationship of a carrier level and a crosstalk level with respect to the optical phase, for a reproduced signal from an optical disk employing a land-groove recording system;

FIG. 13 is a flow chart for explaining the operation of the first embodiment of the optical storage apparatus;

FIG. 14 is a flow chart for explaining a first recognition method;

FIG. 15 is a diagram showing a relationship of a carrier-to-noise ratio and the optical phase;

FIGS. 16A, 16B and 16C respectively are diagrams for explaining the inclination angle of the phase plate;

FIG. 17 is a flow chart for explaining the operation of a second embodiment of the optical storage apparatus according to the present invention;

FIG. 18 is a diagram for explaining the inclination angle of the phase plate;

FIG. 19 is a diagram showing a relationship of the inclination angle of the phase plate and time;

FIG. 20 is a diagram showing a relationship of the inclination angle of the phase plate at a start of a wobble operation and the time;

FIG. 21 is a diagram showing a

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relationship of the inclination angle of the phase plate at a time of synchronization adjustment and the time; and

FIG. 22 is a diagram showing a  
5 relationship of the inclination angle of the phase plate at a time of amplitude adjustment and the time.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

A description will be given of embodiments  
10 of a phase compensation method according to the present invention and an optical storage apparatus according to the present invention, by referring to the drawings.

First, a description will be given of a  
15 first embodiment of the optical storage apparatus according to the present invention. FIG. 1 is a system block diagram showing a structure of this first embodiment of the optical storage apparatus. In this first embodiment of the optical storage  
20 apparatus, the present invention is applied to an optical disk unit. In addition, this first embodiment of the optical storage apparatus employs a first embodiment of the phase compensation method according to the present invention.

As shown in FIG. 1, the optical disk unit  
25 generally includes a control unit 10 and an enclosure 11. The control unit 10 includes a microprocessor unit (MPU) 12 which controls the general operation of the optical disk unit, an  
30 interface 17 which exchanges commands and data between a host unit (not shown) and the optical disk unit, an optical disk controller (ODC) 14 which carries out processes required to read and write data with respect to an optical disk (not shown), a  
35 digital signal processor (DSP) 16, and a memory 18. The memory 18 is used in common by the MPU 12, the ODC 14 and the interface 17, and includes a dynamic

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random access memory (DRAM), a non-volatile memory for storing control programs and information such as flag information, for example. A crystal oscillator 101 is coupled to the MPU 12.

5                   The ODC 14 includes a formatter 14-1 and an error correction code (ECC) processor 14-2. At the time of a write access, the formatter 14-1 divides NRZ write data into sector units of the optical disk 3 and generates a recording format, and  
10                   the ECC processor 14-2 generates and adds an ECC with respect to sector write data units and also generates and adds if necessary a cyclic redundancy check (CRC) code. Further, the ECC processor 14-2 converts the sector data with the encoded ECC into a  
15                   1-7 run length limited (RLL) code, for example.

                  At the time of a read access, a reverse conversion of the 1-7 RLL is carried out with respect to the sector data, and after carrying out the CRC, the error detection and error correction  
20                   using the ECC are carried out in the ECC processor 14-2. Further, the NRZ data in sector units are connected in the formatter 14-2 so as to transfer a NRZ read data stream to the host unit.

                  A write large scale integrated (LSI)  
25                   circuit 20 is provided with respect to the ODC 14. This write LSI 20 includes a write modulator 21 and a laser diode control circuit 22. A control output of the laser diode control circuit 22 is supplied to a laser diode unit 30 which is provided in an  
30                   optical unit of the enclosure 11. The laser diode unit 30 integrally includes a laser diode 30-1 and a monitoring detector 30-2. The write modulator 21 converts the write data into the data format of the pit position modulation (PPM) recording (or mark  
35                   recording) or, a pulse width modulation (PWM) recording (or edge recording).

                  In this embodiment, the data recording and

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reproduction is carried out with respect to the optical disk, such as a rewritable magneto-optical (MO) disk accommodated within a MO cartridge, by the laser diode unit 30. This embodiment employs the PWM recording which records the data in correspondence with the existence and non-existence of marks on the optical disk. The optical disk employs the 1.3 GB recording format using the magnetic super resolution (MSR), and employs the zone constant angular velocity (ZCAV). When the optical disk is loaded into the optical disk unit, intervals of identification (ID) parts which are provided at a plurality of positions in each track turn of the optical disk are recognized, in a state where a laser beam emitted from the laser diode 30-1 is in an on-track state with respect to a predetermined track. The type (recording system, storage capacity and the like) of the optical disk can be recognized from the recognized intervals, by a media type recognizing function of the MPU 12. The recognized type of the optical disk is notified to the ODC 14. The media type recognizing function of the MPU 12 may also recognize the type of the optical disk by reading a control zone of the optical disk.

A read LSI circuit 24 is provided as a read system with respect to the ODC 14. A read demodulator 25 and a frequency synthesizer 26 are provided in the read LSI circuit 24. An ID/MO detector 32 of the enclosure 11 detects the laser beam emitted from the laser diode 30-1 and returned via the optical disk, and a detection signal from this ID/MO detector 32 is input as an ID signal and a MO signal to the read LSI circuit 24 via a head amplifier 34.

The read demodulator 25 of the read LSI circuit 24 includes the functions of circuits such

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The frequency synthesizer 26 is made of a phase locked loop (PLL) circuit having a programmable frequency divider, and generates as a read clock a reference clock having a predetermined specific frequency depending on the zone position on the optical disk.

The read data demodulated in the read LSI circuit 24 is supplied to the read system of the ODC 14, and after carrying out the reverse conversion of the 1-7 RLL, the CRC and the ECC processes are carried out by the encoding function of the ECC processor 14-2 so as to restore the original NRZ data. Next, the formatter 14-1 connects and converts the NRZ sector data into the NRZ read data stream, and this NRZ read data stream is transferred to the host unit via the memory 18 and the interface 17.

A detection signal from a temperature sensor 36 provided in the enclosure 11 is supplied with respect to the MPU 12 via the DSP.16. Based on an environmental temperature within the optical disk unit detected by the temperature sensor 36, the MPU

The MPU 12 controls a spindle motor 40 provided in the enclosure 11 via the DSP 16 and a driver 38. In this embodiment, since the ZCAV is employed as the recording format of the optical disk, the spindle motor 40 is rotated at a constant speed of 3637 rpm, for example.

10 In addition, the MPU 12 controls an  
electromagnet 44 provided in the enclosure 11 via  
the DSP 16 and a driver 42. The electromagnet 44 is  
arranged on a side opposite to the side of the  
optical disk on which the laser beam is irradiated  
15 within the optical disk unit which is loaded with  
this optical disk. This electromagnet 44 supplies  
an external magnetic field on the optical disk at  
the time of the recording and erasure. In the case  
of the optical disk having the 1.3 GB recording  
20 format and using the MSR, the external magnetic  
field is also supplied to the optical disk at the  
time of the MSR reproduction.

The DSP 16 is provided with a servo function for positioning the laser beam from the laser diode 30-1 with respect to the optical disk, and functions as a seek controller and an on-track controller which enable the laser beam to seek a target track and to be positioned on the target track. The seek control and the on-track control may be carried out simultaneously in parallel with the write access or the read access of the MPU 12 with respect to a host command.

In order to realize the servo function of the DSP 16, a focus error signal (FES) detector 45 is provided in the optical unit of the enclosure 11 so as to detect the laser beam emitted from the laser diode 30-1 and returned via the optical disk.

A FES detection circuit 46 generates a FES E1 from a detection signal received from the FES detector 45, and inputs this FES E1 to the DSP 16.

5 A tracking error signal (TES) detector 47 is also provided in the optical unit of the enclosure 11 so as to detect the laser beam emitted from the laser diode 30-1 and returned via the optical disk. A TES detection circuit 48 generates a TES E2 from a detection signal received from the  
10 TES detector 47, and inputs this TES E2 to the DSP 16. The TES E2 is also input to a track zero crossing (TZC) detection circuit 50, and this TZC detection circuit 50 generates a TZC signal E3 which is input to the DSP 16.

15 A lens position sensor 54 is provided in the enclosure 11. This lens position sensor 54 detects a position of an objective lens through which the laser beam is irradiated on the optical disk. A lens position detection signal (LPOS) E4  
20 from the lens position sensor 54 is input to the DSP 16. The DSP 16 controls and drives a focus actuator 60, a lens actuator 64 and a voice coil motor (VCM) 68 via corresponding drivers 58, 62 and 66, so as to control the position of a beam spot formed by the  
25 laser beam on the optical disk.

A phase plate which will be described later is provided in the reproducing optical system of the optical unit within the enclosure 11. A phase plate position detector 91 detects a position  
30 of the phase plate and supplies a detection signal to a position detection circuit 92. The position detection circuit 92 generates a position detection signal E5 which indicates the position of the phase plate, and inputs this position detection signal E5  
35 to the DSP 16. Accordingly, the MPU 12 can detect the position of the phase plate via the DSP 16. The MPU 12 controls and drives a phase plate actuator 94

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FIG. 2 is a cross sectional view showing a  
5 general structure of the enclosure 11. As shown in  
FIG. 2, the spindle motor 40 is provided within a  
housing 67. By inserting a MO cartridge 70 into the  
housing 67 from the side of an inlet door 69, an  
optical disk (MO disk) 72 accommodated within the MO  
0 cartridge 70 engages a hub on a rotary shaft of the  
spindle motor 40, thereby loading the optical disk  
72 with respect to the optical disk unit.

A carriage 76 is provided below the optical disk 72 within the loaded MO cartridge 70. This carriage 76 is freely movable in a direction which traverses tracks on the optical disk 72 when driven by the VCM 64. An objective lens 80 is mounted on the carriage 76. The laser beam emitted from the laser diode 30-1 which is provided within a fixed optical system 78 is reflected by a mirror 82, and is irradiated on the recording surface of the optical disk 72 via the objective lens 80, thereby forming a beam spot on the recording surface. The movement of the objective lens 80 along an optical axis is controlled by the focus actuator 60 of the enclosure 11 shown in FIG. 1. In addition, the objective lens 80 is movable in a radial direction which traverses the tracks on the optical disk 3 by the lens actuator 64, within a range of several tens of tracks. The position of the objective lens 80 mounted on the carriage 76 is detected by the lens position sensor 54 shown in FIG. 1. The lens position sensor 54 outputs the lens position detection signal E4 which takes a value zero at a neutral position where the optical axis of the objective lens 80 is perpendicular to the recording surface of the optical disk 72, and has a



FIGS. 3A and 3B respectively are diagrams showing a structure of an important part within the enclosure 11. FIG. 3A is a plan view, and FIG. 3B is a bottom view. As shown in FIGS. 3A and 3B, the spindle motor 40, the carriage 76 and the like are provided on a base 100 of the enclosure 11 together with a phase compensation mechanism 101.

The fixed optical system 78 includes a collimator lens 110, beam splitters 111, 112 and 113, a lens system 114, a second phase plate 115, the phase compensation mechanism 101, and a lens system 116. The laser beam emitted from the laser diode 30-1 is irradiated on the optical disk 72 (not shown) via the collimator lens 110, the beam splitter 111 and the mirror 82. The reflected beam from the optical disk 72, which is obtained via the beam splitter 111, is supplied to the lens system 114 via the beam splitters 112 and 113 on one hand, and is supplied to the second phase plate 115 via the beam splitter 112 on the other. The beam which passes through the lens system 114 which includes a condenser lens, is detected by the FES detector 45 and the TES detector 47. The beam obtained from the second phase plate 115 is detected by the ID/MO detector 32 via the phase compensation mechanism 101 and the lens system 116. The lens system 116 includes a Wollaston prism and a condenser lens. In FIG. 4, MOX indicates an optical axis of the

The reproducing optical system within the enclosure 11 generally includes the beam splitters 112 and 113, the lens system 114, the second phase plate 115, the phase compensation mechanism 101 and the lens system 116.

The phase compensation mechanism 101 is mounted on the base 100 by fixing screws 104 as shown in FIG. 5, so that an inclination angle of a phase plate within the phase compensation mechanism 101, which will be described later, is adjustable in a range of  $-\theta$  to  $+\theta$ .

35           As shown in FIG. 6, the phase compensation  
mechanism 101 generally includes a holder 121 which  
is rotatably provided on the base 100, and a (first)

The holder 121 of the phase compensation mechanism 101 is driven by the coil 123 and the magnet 124, and the inclination angle of the phase plate 122 is adjustable in the range of  $-\theta$  to  $+\theta$ . The inclination angle of the phase plate 122 is detected by the detector 125 and the reflection mirror 126. More particularly, the detector 125 is made up of a light emitting part and a light receiving part, and light emitted from the light emitting part is reflected by the reflection mirror 126 and detected by the light receiving part. As will be described later, the reflection mirror 126 includes a bright portion which is formed by evaporation or the like of aluminum and has a high reflectivity, and a dark portion which is formed by evaporation or the like of carbon and has a low reflectivity.

FIG. 7 shows a state where the phase plate 122 is positioned approximately at a center of the adjustable range and is inclined with respect to the optical axis MOX of the returning MO signal by an angle which gives an amount of phase compensation equal to 0 degree. The angle of the phase plate 122 with respect to the optical axis MOX of the

returning MO signal corresponds to the inclination angle of the phase plate 122.

FIG. 8 is a diagram for explaining an embodiment of the reflection mirror 126, and shows a state where the detector 125 is seen through the reflection mirror 126. In FIG. 8, the detector 125 is made up of a light emitting part 125-1 and a light receiving part 125-2. The reflection mirror 126 is made up of a bright portion 126-1 and a dark portion 126-2 which are partitioned by an oblique brightness boundary line 126-3. In other words, the brightness boundary line 126-3 is inclined by a predetermined inclination angle with respect to the direction in which the light emitting part 125-1 and the light receiving part 125-2 of the detector 125 are arranged, that is, with respect to a vertical direction in FIG. 8. In FIG. 8, an arrow indicates a relative moving direction of the detector 125 and the reflection mirror 126.

FIG. 9 is a diagram for explaining another embodiment of the reflection mirror 126, and shows a state where the detector 125 is seen through the reflection mirror 126. In FIG. 9, the detector 125 is made up of a light emitting part 125-1 and a light receiving part 125-2. The reflection mirror 126 is made up of a bright portion 126-1 and a dark portion 126-2 which are partitioned by a vertical brightness boundary line 126-3. In FIG. 9, an arrow indicates a relative moving direction of the detector 125 and the reflection mirror 126.

FIG. 10 is a diagram showing a relationship of the inclination angle of the phase plate 122 and an output of the detector 125. In FIG. 10, the ordinate indicates the output (detector output) of the detector 125 in arbitrary units, and the abscissa indicates the inclination angle of the phase plate 122 in arbitrary units. When an oblique

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edge detection is carried out using the reflection mirror 126 shown in FIG. 8, the relative positions of the detector 125 and the reflection mirror 126 change as the phase plate 122 turns, and the  
5 detector output changes as indicated by a dotted line I in FIG. 10. In addition, when a normal edge detection is carried out using the reflection mirror 126 shown in FIG. 9, the relative positions of the detector 125 and the reflection mirror 126 change as  
10 the phase plate 122 turns, and the detector output changes as indicated by a solid line II in FIG. 10. By controlling the coil 123 based on such a detector output, the phase 122 is locked to a desired inclination angle with respect to the optical axis  
15 MOX of the returning MO signal. When mounting the phase compensation mechanism 101 on the base by the fixing screws 104, the inclination angle of the phase plate 122 is locked in such a manner.

As may be seen from FIG. 10, the detector  
20 output becomes more gradual when the oblique edge detection is used as compared to the case where the normal edge detection is used. Accordingly, even when offsets of circuits such as the position detection circuit 92 shown in FIG. 1 are accumulated,  
25 it is possible to lock the phase plate 122 at an inclination angle closer to the desired inclination angle by use of the reflection mirror 126 shown in FIG. 8 than by use of the reflection mirror 126 shown in FIG. 9, and a more accurate amount of phase  
30 compensation can be given by the reflection mirror 126 shown in FIG. 8.

FIG. 11 is a diagram showing a  
relationship of an optical phase and the inclination angle of the phase plate 122. In FIG. 11, the  
35 ordinate indicates the optical phase (degrees), and the abscissa indicates the inclination angle (degrees) of the phase plate 122. For example, when

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using an optical phase in a range of approximately -30 degrees to approximately +30 degrees, it may be seen from FIG. 11 that the phase plate 122 should be used with an inclination angle in a range of approximately +11.5 degrees to approximately +18.5 degrees or in a range of approximately -11.5 degrees to approximately -18.5 degrees.

FIG. 12 is a diagram showing a relationship of a carrier level and a crosstalk level with respect to the optical phase, for a reproduced signal from the optical disk 72 employing the land-groove recording system. In FIG. 12, the ordinate indicates the carrier level (dBm) and the crosstalk level (dBm), and the abscissa indicates the optical phase (degrees). In addition, a symbol  $\bigcirc$  indicates the carrier level of the reproduced signal from the groove of the optical disk 72, a symbol  $\bullet$  indicates the carrier level of the reproduced signal from the land of the optical disk 72, a symbol  $\times$  indicates the crosstalk level from the adjacent grooves of the optical disk 72, and a symbol  $\square$  indicates the crosstalk level from the adjacent lands of the optical disk 72. By carrying out the phase compensation using the phase plate 122, the carrier level increases and the crosstalk level from the adjacent tracks decreases. For example, when using an optical phase in a range of approximately -30 degrees to approximately +30 degrees, it may also be seen from FIG. 12 that the phase plate 122 should be used with an inclination angle in a range of approximately +11.5 degrees to approximately +18.5 degrees or in a range of approximately -11.5 degrees to approximately -18.5 degrees.

Therefore, according to this embodiment, it is possible to control the inclination angle of the phase plate 122 to an arbitrary inclination

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angle to give an optimum amount of phase compensation with respect to the reproduced signal, by detecting the inclination angle of the phase plate 122 and controlling the inclination angle of the phase plate based on the detected result. The inclination angle of the phase plate 122 may be controlled and switched between an inclination angle with respect to the reproduced signal from the land of the optical disk 72 and an inclination angle with respect to the reproduced signal from the groove of the optical disk 72. In addition, it is possible to appropriately control the inclination angle of the phase plate 122 depending on the optimum amount of phase compensation to suit each type of optical disk used. For this reason, it is possible to give an optimum amount of phase compensation with respect to each type of optical disk, regardless of whether the optical disk used employs the land recording system or the land-groove recording system.

FIG. 13 is a flow chart for explaining the operation of this first embodiment of the optical storage apparatus. The process shown in FIG. 13 is carried out by the MPU 12 shown in FIG. 1. First, a step S1 determines whether the reproduced signal from the optical disk 72 is a reproduced signal from the land or a reproduced signal from the groove, based on position information which is recorded on the optical disk 72. A step S2 sets a target position, that is, a target inclination angle, of the phase plate 122, depending on whether the reproduced signal is from the land or the groove of the optical disk 72. The memory 18 prestores a correlation table CT which indicates a correlation of a target optical phase with respect to each type of optical disk 72 and a corresponding target position of the phase plate 122, with respect to both the land and the groove. Accordingly, the step

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S2 reads the target position of the phase plate 122 from the correlation table CT depending on whether the track being reproduced is provided on the land or the groove, that is, whether a land signal reproduction or a groove signal reproduction is being carried out. A step S3 drives and controls the phase plate actuator 94 depending on the target position of the phase plate 122 set in the step S2, and the process ends.

10           The optical phase of the reproducing optical system as a whole within the enclosure 11 differs for each individual optical disk unit due to inconsistencies. For this reason, it is necessary to recognize a reference optical phase when mounting the phase compensation mechanism 101 in the optical disk unit. A method of recognizing the optical phase is not limited to a particular method, but for example, any one of following first through third recognition methods may be employed.

20           According to the first recognition method, a reference optical disk from which an optimum reproduced signal is obtained when the optical phase is 0 degree, for example, is used. In addition, an offset is added to the signal which drives and controls the phase plate actuator 94, and a position of the phase plate 122 where the optimum reproduced signal is obtained from the reference optical disk is recognized as the position where the optical phase of the reproducing optical system as a whole is 0 degree. A correlation of the detection output of the phase plate position detector 91 and the inclination angle and the amount of phase compensation of the phase plate 122 may be known by carrying out an evaluation in advance. Hence, when the inclination angle of the phase plate 122 where the optical phase can be recognized as being 0 degree is known, it is possible to give the optimum

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amount of phase compensation with respect to both the case of the land signal reproduction and the case of the groove signal reproduction, by changing the inclination angle of the phase plate 122 based on the known value. The optimum reproduced signal refers to a signal which is reproduced from a track and having a maximum carrier-to-noise ratio (CNR), a minimum DC deviation, and/or a minimum crosstalk level from the adjacent tracks which are adjacent to the track which is being reproduced.

FIG. 14 is a flow chart for explaining the first recognition method. In FIG. 14, those steps which are the same as those corresponding steps in FIG. 13 are designated by the same reference numerals, and a description thereof will be omitted.

In FIG. 14, a step S11 adds an offset to the target position of the phase plate 122, and drives and controls the phase plate actuator 94. A step S12 decides whether or not an optimum reproduced signal is obtained from the reference optical disk. If the decision result in the step S12 is NO, the process returns to the step S11, and a further offset is added to the target position of the phase plate 122. On the other hand, if the decision result in the step S12 is YES, a step S13 recognizes the position of the phase plate 122 where the optimum reproduced signal is obtained from the reference optical disk as being a position where the optical phase of the reproducing optical system as a whole is 0 degree, and stores this position of the phase plate 122 in the memory 18 as the target position. More particularly, the step S13 creates the correlation table CT within the memory 18. The process ends after the step S13.

FIG. 15 is a diagram showing a relationship of the CNR and the optical phase for the land signal reproduction from the reference

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optical disk. In FIG. 15, the ordinate indicates the CNR (dB), the abscissa indicates the optical phase (degrees), and CNRMAX indicates a maximum value of the CNR. In addition, FIGS. 16A, 16B and 16C respectively are diagrams for explaining the inclination angle of the phase plate 122. FIG. 16A shows a case where the inclination angle of the phase plate 122 is  $\alpha$  degrees, FIG. 16B shows a case where the inclination angle of the phase plate 122 is  $\alpha + \beta$  degrees, and FIG. 16C shows a case where the inclination angle of the phase plate 122 is  $\alpha + \beta + \Delta \beta$  degrees.

In FIG. 15, ① indicates a case where the inclination angle of the phase plate 122 is as shown in FIG. 16A, ② shows a case where the inclination angle of the phase plate 122 is as shown in FIG. 16B, and ③ shows a case where the inclination angle of the phase plate 122 is as shown in FIG. 16C. In FIG. 15, the CNR becomes the maximum value CNRMAX in the case ③, and thus, the position of the phase plate 122 where the optimum reproduced signal is obtained in the process shown in FIG. 14 is when the inclination angle of the phase plate 122 is  $\alpha + \beta + \Delta \beta$  degrees as shown in FIG. 16C.

According to the second recognition method, a reference optical disk from which an optimum reproduced signal is obtained when the optical phase is 0 degree, for example, is used, and the phase plate actuator 94 is driven and controlled, so as to lock the phase plate 122 at the inclination angle where the amount of phase compensation becomes 0 degree according to design. Then, the rotary position of the entire phase compensation mechanism 101 is adjusted with respect to the optical disk unit, and the phase compensation mechanism 101 is fixed at the rotary position where the optimum reproduced signal is obtained. Thereafter, the

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optimum amount of phase compensation is given with respect to both the case of the land signal reproduction and the groove signal reproduction, by a procedure similar to that employed in the first  
5 recognition method described above.

According to the third recognition method, a reference optical disk from which an optimum reproduced signal is obtained when the optical phase is 0 degree, for example, is used, and the phase  
10 plate actuator 94 is driven and controlled, so as to lock the phase plate 122 within the phase compensation mechanism 101 at the inclination angle where the amount of phase compensation becomes 0 degree according to design. Then, the position of  
15 the second phase plate 115 for finely adjusting the optical phase to 0 degree is adjusted so that an optimum reproduced signal is obtained, before finally fixing the position of the second phase plate 115 in the optical disk unit.

20 Therefore, according to this embodiment, it is possible to carry out an appropriate phase compensation, and reproduce signals from both the optical recording medium employing the land recording system and the optical recording medium  
25 employing the land-groove recording system. In addition, it is possible to reproduce signals from optical recording media having different specifications, by carrying out an appropriate phase compensation. Hence, the first and second problems  
30 of the prior art described above can be eliminated.

Next, a description will be given of a second embodiment of the optical storage apparatus according to the present invention. The basic structure of this second embodiment of the optical  
35 storage apparatus is the same as that of the first embodiment described above, and a description and illustration thereof will be omitted. In this

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second embodiment of the optical storage apparatus,  
the present invention is applied to an optical disk  
unit. This second embodiment of the optical storage  
apparatus employs a second embodiment of the phase  
5 compensation method according to the present  
invention.

In this second embodiment, the inclination  
angle of the phase plate 122 of the phase  
compensation mechanism 101 is varied in synchronism  
10 with the rotation of the optical disk 72 so that a  
DC fluctuation of the reproduced signal (MO signal)  
becomes constant and minimum within one revolution  
of the optical disk 72, that is, within one track  
(or the same track turn), within one zone (or same  
15 zone), and/or within a plurality of tracks, so that  
it is possible to always obtain a reproduced signal  
within an optimum optical phase.

In addition, it is possible to always  
obtain a reproduced signal with an optimum optical  
20 phase, by varying the inclination angle of the phase  
plate 122 of the phase compensation mechanism 101 in  
synchronism with the rotation of the optical disk 72,  
so that the crosstalk level from the tracks adjacent  
to the track which is being reproduced is minimized.

25 Control data for varying the inclination  
angle of the phase plate 122 so that the fluctuation  
of the MO signal becomes constant and minimum within  
one revolution of the optical disk 72 (one track),  
within the same zone and/or within the plurality of  
30 tracks, and/or so that the crosstalk level from the  
adjacent tracks becomes a minimum, may be stored in  
the memory 18. In this case, by controlling the  
inclination angle of the phase plate 122 based on  
the control data stored in the memory 18 during the  
35 signal reproduction, it is possible to always obtain  
the reproduced signal with the optimum optical phase.  
Moreover, the inclination angle of the phase plate

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122 may be controlled within one revolution of the optical disk 72 (one track), within the same zone and/or within the plurality of tracks as described above, with respect to each of the land and the  
5 groove of the optical disk 72.

FIG. 17 is a flow chart for explaining the operation of this second embodiment of the optical storage apparatus. In FIG. 17, a step S21 reads the target position of the phase plate 122 from the  
10 correlation table CT which is stored in the memory 18. A step S22 carries out a wobble operation by varying the target position which is read from the memory 18. A step S23 carries out a synchronization adjustment so that the wobble operation is carried  
15 out in synchronism with the rotation of the optical disk 72.

FIG. 18 is a diagram for explaining the inclination angle of the phase plate 122 with respect to the optical axis MOX of the returning MO  
20 signal. FIG. 19 is a diagram showing a relationship of the inclination angle of the phase plate 122 and time. In FIG. 19 and FIGS 20 through 22 which will be described later, the ordinate indicates the inclination angle of the phase plate 122 in  
25 arbitrary units, and the abscissa indicates the time (t) in arbitrary units. In FIG. 19, the inclination angle of the phase plate 122 which gives an ideal amount of phase compensation (optical phase error) in one revolution period of the optical disk 72 is  
30 approximated by a sine curve. In FIGS. 19 through 22, T denotes one revolution period of the optical disk 72, and  $\Delta\gamma$  denotes a variable range of the inclination angle of the phase plate 122.

FIG. 20 is a diagram showing a  
35 relationship of the inclination angle of the phase plate 122 at a start of the wobble operation in the step S22 and the time, and the inclination angle

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5 wobble operation. In addition, FIG. 21 is a diagram showing a relationship of the inclination angle of the phase plate 122 at a time of the synchronization adjustment in the step S23 and the time, and the inclination angle during the initial wobble  
10 operation is indicated by a dotted line, and the inclination angle after the synchronization adjustment is indicated by a thin solid line.

Returning now to the description of the process shown in FIG. 17, a step S24 decides, of the reproduced signal, whether or not the DC fluctuation of the MO signal is a minimum or, whether or not the crosstalk level from the adjacent track is a minimum. The process returns to the step S23 if the decision result in the step S24 is NO. If the decision result in the step S24 is YES, a step S25 stores the synchronization error  $\Delta T$  with respect to the rotation period of the optical disk 72 during the wobble operation in the memory 18. A step S26 carries out an amplitude adjustment of the wobble operation, and adjusts the inclination angle of the phase plate 122 to fall within the variable range  $\Delta \gamma$ . FIG. 22 is a diagram showing a relationship of the inclination angle of the phase plate 122 at a time of amplitude adjustment of the wobble operation and the time, and the inclination angle after the amplitude adjustment is indicated by a thin solid line.

A step S27 decides, of the reproduced signal, whether or not the DC fluctuation of the MO  
35 signal is a minimum or, whether or not the crosstalk level from the adjacent tracks is a minimum. The process returns to the step S26 if the decision

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time when a predetermined time has elapsed, at  
predetermined time intervals, at a time when a  
temperature change occurs, and the like. In this  
case, the correction values are also stored in the  
5 memory 18. By using the stored correction values,  
it is possible to appropriately correct the control  
data to suit the individual optical disk 72 or the  
environmental change, and the accuracy of the signal  
reproduction is further improved. The correction  
10 values stored in the memory 18 may be cleared when  
the optical disk 72 is unloaded and ejected from the  
optical disk unit.

Further, the present invention is not  
limited to these embodiments, but various variations  
15 and modifications may be made without departing from  
the scope of the present invention.

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